# NOTES AND LITERATURE.

## ZOÖLOGY.

**Temperature of Insects.** — Professor Bachmetjew's[1] paper is one of those rare publications which is full of interest not only to the specialist in entomology but to biologists in general. The Russian author, with the equipment of the trained physicist, approaches a subject that has often been studied before, and after treating it in an exhaustive manner reaches new and important results, which would carry conviction in their very simplicity, even if they were not substantiated step by step by detailed tables of observations. The work of all previous investigators in determining the vital temperature of insects is briefly and critically reviewed as a preface to each of the main sections of the work.

In order to determine the temperatures, the insect was spitted through the thorax on a thermoelectric needle consisting of fused manganin and steel wires connected with a galvanometer. A detailed account of the somewhat complicated apparatus and the method of using it are given in an appendix (pp. 138–142). A number of different insects, mostly larger moths, butterflies, and beetles, both pupal and imaginal, were used in the experiments.

The first part of the work is devoted to a consideration of the body temperature of insects. In his earlier experiments, Bachmetjew came to the conclusion that the temperature of the insect body varies within very considerable limits, apparently without any serious consequences to the life of the animal. He found, moreover, that in resting insects the temperature is the same or very nearly the same as that of the surrounding air. Subsequent experiments, however, led him to conclude that this is true only under ordinary conditions of moisture, temperature, etc., since these factors, when abnormal, have a very pronounced effect on the body temperature. Under normal conditions, when the temperature of the atmosphere is raised, the temperature of the insect, though rising, lags at first more and more behind

[1] Bachmetjew, P. Temperaturverhältnisse bei Insekten. Experimentelle entomologische Studien vom physikalisch-chemischen Standpunkt aus. Bd. i, pp. 4–160. Leipzig, Wilhelm Engelmann, 1901.

that of the atmosphere, and only begins to approach atmospheric temperature just before partial heat paralysis of the wing muscles sets in. After death the temperature of the insect and the air are the same. But when the air is very damp the body temperature of the insect is higher than that of the air. This is explained as due to evaporation of the body fluids and to respiration, the former having a tendency to diminish, the latter to raise, the temperature of the insect. Bachmetjew predicts that the study of the dependence of the body temperature on that of the air, under different conditions of moisture, will ultimately enable us to determine the metabolism of these animals, and hence their vitality at different temperatures.

The influence of the activity of the insect on its body temperature, long since noted by Newport (1837) and others, is exhaustively studied by Bachmetjew. While a moth is moving its wings its body temperature keeps rising, but falls suddenly with the cessation of this movement. The insect was studied under three conditions: first, at the ordinary temperature of the room; second, at a higher temperature in the thermostat; third, at a lower temperature in a cold-air bath. Experiments conducted at room temperature show that the moth (Sphingid) is incapable of raising its own temperature higher than 38.5° C. by means of muscular movement. Fluttering of the wings does not produce as high a temperature as "humming." At about 38° C. the insect often suddenly changed from humming to fluttering, or rested completely. Bachmetjew interprets this change as due to partial heat paralysis of the muscles. It is a transitory phenomenon, which disappears with the sinking of the temperature during rest to that of the surrounding atmosphere. The temperature at which the wing muscles are paralyzed (in *Deilephila euphorbiæ*) increases with an increase of the temperature (at ordinary moisture) and reaches 45.5° C., after which the moth loses the power of humming. Complete, *i.e.*, no longer transitory, heat paralysis of these muscles supervenes at a body temperature of 49.7° C. In somewhat moister air this result does not set in till 53° C. is reached. In a single experiment on Deilephila at low atmospheric temperature the muscle paralysis also appeared, but at a lower temperature. At a body temperature of − 0.5° C. all movements ceased, fluttering began at 12° C., and humming not till 20° C. had been reached. It would seem, therefore, that the temperature of partial paralysis of the wing muscles is directly proportional to the body temperature of the insect, as is also the case for higher temperatures. According to Bachmetjew, these effects of partial paralysis play a great rôle in the production

of color aberrations in butterflies. He also suggests that further study of these effects may explain why so many moths are nocturnal, while the butterflies are diurnal. Some experiments on the influence of respiration showed that Deilephila at 29.4° C. atmospheric temperature could raise its body temperature through at least 3° C. by means of breathing alone.

The second and more important portion of Bachmetjew's paper deals with the vital extremes of temperature. It is divided into two sections, one dealing with the maximum, the other with the minimum temperature. The vital maximum is the highest temperature at which an insect is able to live. Experiments on *Saturnia pyri* showed that the insect becomes very restless at a temperature of about 39° C. and dies when the body reaches a temperature of 46° C. This is also very near the lethal temperature for plants (Sachs and Schultze). This lethal temperature, however, depends on a number of factors. In general, it may be said that if the insect at high temperature first, has not been exhausted, *i.e.*, has been artificially fed; second, is not desiccated, *i.e.*, is in a sufficiently moist atmosphere; and third, presents the same conductivity to heat and the same body size for a given species, — its life will depend only on the coagulation or non-coagulation of its body fluids. Hence, the vital maximum is only another expression for the coagulation point of the body fluids. And if one knew the amount of water in the insect's albumins, especially of those albumins essential to life, the question of the vital maximum would resolve itself merely into a determination of the amount of water.

Bachmetjew's study of the vital minimum, *i.e.*, the lowest temperature at which an insect can live, brought out some startling results. He found from experiments on a great number of insects that different species died at very different temperatures. But his most interesting results refer to the critical point, which is the temperature to which the fluids of the insect may be undercooled before they begin to congeal and then suddenly rise in temperature till the normal congealing point is reached. Bachmetjew points out the resemblance of this phenomenon to the well-known undercooling of water, which can be cooled to − 25° C. without freezing, but at once rises to 0° C. to freeze. Bachmetjew discovered the undercooling of the body fluids of insects by accident in an experiment on *Saturnia pyri* ♀. The insect was cooled to − 9.4° C., whereupon within a minute's time the temperature bounded up to − 1.4° C., the normal congealing point of the body fluids, and then remained constant for

eleven minutes. In this case the critical point is $-9.4°$ C., and $-1.4°$ C. is the normal congealing point. This insect revived within an hour after the experiment, and laid eggs on the following day. From this Bachmetjew concludes that the mere congealing of the body fluids is not lethal. In a second experiment a moth of the same species showed a critical point of $-11.6°$ C. (4.25 P.M.), whereupon the temperature rose at once to $-1.1°$ C. The insect was kept in the cold, the temperature of its body again sinking to $-15.6°$. At 6.15 P.M. it was removed to the temperature of the room, but could not be revived. It follows that the insect dies if its body is still further cooled after the rebound (the limits being not necessarily higher than $-2.5°$ C. nor lower than $-15.6°$ C.), or, as a general rule, it may be stated that the insect dies if its temperature be again reduced to about the point from which it rebounded. Further experimentation on this interesting subject led to the following general conclusions here briefly transcribed. The extreme degrees of undercooling of the fluids differ in different insects, and these extremes occur at nearly the same rate of cooling. The critical point, so far as its absolute minimum is concerned, is greater in pupæ than in imaginal moths and butterflies, whereas the maximum differs in pupæ and imagines. Owing to lack of material, the behavior of the larvæ could not be determined. With respect to sex, the degree of undercooling of the fluids in normal specimens is lower in the males than in the females. This is also the case after brief fasting; after protracted fasting, however, the degree of undercooling is lower in the males, but finally becomes the same in both sexes. On the other hand, the normal congealing point of the fluids is lower in the females than in the males. After fasting, it is the same in both sexes; but after protracted fasting, the relation is again reversed. Further investigation of this question showed that the insect juices have a lower critical point when the insect is fasting, but so far as its absolute magnitude is concerned, it diminishes on continued starvation. Repetition of undercooling gave the following results: On freezing a second time strong Lepidoptera exhibit a much greater degree of undercooling than on the first freezing; on being frozen a third time the fluids show almost no undercooling. This is also shown by weak Lepidoptera on the second cooling. Bachmetjew also studied the influence of the fluid coefficient on undercooling. If $M$ be taken as the total weight of the living insect, and $P$ its weight after drying on a water bath for a long time at a temperature of $115°$ C., $M-P$

would represent the weight of the fluids which leave the body on evaporation at this temperature. The relation

$$\frac{M-P}{M}=q$$

is known as the fluid coefficient and signifies the percentage of fluids in a unit of weight of the living insect body. Experiment shows that the smaller the fluid coefficient the lower lies the normal congealing point of the fluids. The critical point is also influenced by the fluid coefficient, but this influence cannot be stated in general terms till the composition of the fluids has been further studied. Time also influences the critical point. If the temperature ($t$) to which the insect is undercooled coincides at the same rate of cooling with the critical point ($K_1$), the juices at once begin to congeal (*i.e.*, time $= o$); but if $t$ does not coincide with $K_1$, the congealing of the fluids is delayed in proportion to this difference ($K_1 - t$).

Undoubtedly Bachmetjew's results are of a far-reaching character and will ultimately form the basis for important work along theoretical lines in physiology, and for practical applications of great moment (in economic entomology, *e.g.* !), for they throw light on the geographical and climatic distribution of organisms, the resistance of animals and plants to cold and heat, and the problems of anabiosis. That Bachmetjew himself is very sanguine concerning the results that may ultimately flow from his work is apparent when he says. "Es eröffnet sich somit ein ganz neues Gebiet für die Forscher, und wer weiss, ob die Zeit nicht nahe ist, wo man den märchenhaften hundertjährigen Schlaf auch bei Menschen künstlich hervorrufen könnte! Die Insekten wenigstens bieten die Möglichkeit dazu."

W. M. W.

**An Important Paper on Phoridæ.** — Theodor Becker, of Liegnitz, Prussia, has recently published a work[1] of 100 pages, with five plates, on the family Phoridæ, which deserves notice among zoölogists in general because it is one of the finest pieces of systematic work that has been published on the Diptera.

The family Phoridæ includes only small species, generally from two to four millimeters in length, which do not offer to the observer with a hand lens a satisfactory series of specific characters. The genus Phora was early described and generally recognized from its

[1] *Abhandlungen der k. k. zool.-botan. Gesellschaft in Wien*, Bd. i, Heft 1, 1901.